Brno University of Technology
Faculty of electrical Engineering
Technická 3058/10, 616 00 Brno 16, Czechia

Reviewer Assessment of Master's thesis

Department: Department of Electrical Power Engineering

Student name: **Jan Klusáček**

Study program: Power Electrical and Electronic Engineering (N2643)

Supervisor of the master's thesis: **Michal Vrána, MSc.**

Reviewer of the master's thesis: **Adam Collin, Ph.D.**

Title of master's thesis:

Implementation of control algorithm in application with several accumulation systems

Final evaluation of master's thesis:

I recommend this master's thesis for final defence. Total number of points: 82

Verbal evaluation:

This Master's research project was focussed on the design, implementation and evaluation of a control system encompassing a small-scale electrical system comprised of a local generator, local load and two energy accumulation devices. Such a system is representative of, for example, a single household or community energy scheme, which are expected to increase in number in the future. As such, this area of work is both interesting and important.

The presented research covers several aspects of the electrical engineering discipline and the student is to be commended for successfully developing and interfacing the multifaceted hardware and software systems. The design approach was clear, with emphasis placed on utilising, where possible, off-the-shelf components. Using technical knowledge, the student was able to justify where this was possible and where this was not possible. Where off-the-shelf solutions were not available, e.g. the EMC filter and the heat load control switch, the student demonstrated a clear approach to developing solutions based on suitable technical literature and/or design heuristics. Further value could have been added by including some additional results comparing the practical systems with the expected values calculated from the theory.

The hardware elements, including embedded software, were controlled by a master algorithm and this physical realisation provides the most tangible output of the project. A brief literature review of existing control algorithms was presented to provide context for the proposed algorithm. This review could have been extended to include more sources, and a table comparing the key features would have been nice way to summarise and directly compare different algorithms. This could also have been used to emphasise the unique features of the system/algorithm developed in this thesis. Some further attention is required in the presentation of the algorithm as, for example, in Figure 33, it appears that the evaluation of the state ‘SOC < 100’ can never be FALSE if ‘TEMP < 100 & SOC < 100’ is TRUE. As such the state ‘Battery is charged’ is never reached. The same is true for the evaluation of the state ‘TEMP < 100’ in the same figure. The addition of a priority coefficient is an interesting concept but further details of this are required to emphasize the importance of this idea for the user and system operation. Similarly, the discussion of the results is a little superficial and more value could have been added by explaining in more detail the design of the experiment (why each interval was selected/what it would show/how it would test the system). However, the annotation used in the figures is a good communication device and helps to illustrate some of the key points.

The limited discussion of the results is the main limitation of the thesis. Overall, the thesis was easy to read and logically structured, and the level of detail afforded to each subsystem/component was, generally, proportional to its complexity. The figures were clear and added value. The language utilised, although rather brief in places, was suitable for demonstrating a good understanding of the subject matter.

In conclusion, the work presented in the thesis demonstrates a high level of understanding of a range of electrical engineering topics and can be considered satisfactory for the requirements of a Master’s degree.

This completes the verbal evaluation.

Some editorial changes and information/discussions which could be clarified/improved in the text follow. Finally, some possible questions for use during the thesis defence session are listed.

Suggested minor/editorial changes

#	Page	Comment
1	12, 13, 14, 24 etc	Maximum is preferred to maximal
2	7, 20, 28, 51	Parameterization (typo)
3	13	Heat sink (typo)

4	13	Correct Units of Rd,A
5	13	Resistance of damping resistor (typo)
6	14	Perhaps the SI units of s should be used for time quantities?
7	14	There is no difference in the definition of Z1(s) – Z3(s). Perhaps they could be replaced with a single Zn(s) definition.
8	18	kWp is not defined
9	20	LabVIEW (by… as a system-design platform. (typo)
10	22	O_2 (typo)
11	22	SOC not included in Table of abbreviations
12	24	Replace 'Therefore, the BMS…' with 'In this project, the BMS …'.
13	25	The red curve in Figure 6 does not appear to serve any purpose. Perhaps axes/units could be added to help convey a message
14	26	SOH not included in Table of abbreviations
15	31	The power factor cannot be dynamic and fixed. Suggest to remove 'fixed'
16	35	IGBT transistor (delete transistor)
17	42	Caption of Figure 19 should be updated as the load response is also shown. Also, the legend should be updated to use R_{l}, to avoid confusion
18	56	S_{PWM} is not defined in text
19	61	Incorrect direction of comparison equality signs? SOC should be less than 100? The meaning of the 1 in these columns should also be defined
20	65	Incorrect direction of comparison equality signs? SOC should be less than 100? The meaning of the 1 in these columns should also be defined

Some additional comments for clarification:

- In Section 2.2 both space and water heating are mentioned but, following this, only water heating is explicitly mentioned. It would be useful clearly state this aspect of the project scope during the introductory aspects, e.g. in Section 2.2. itself, to avoid any confusion.
- Figure 2 is very nice and clearly visualizes the overall system. However, the variable names Plocal and Pinv are not very representative of their quantities. For example, Pinv is not simply the power flow from/to the inverter, as both Plocal and Ppv are downstream. Perhaps these could be renamed, or the labels could be introduced in the text before the figure and described. Furthermore, household consumption could be variable name (Phh?). For consistency the same subscripts could be used later in the thesis, for example in Figure 36 and explicitly used in the discussions in Section 5. For example, in Figure 11 subscripts G end E are used for currents – applying a standard label system would improve clarity.
- In Section 3.1, it is stated that the battery will charge during off peak periods and provides energy during the peak period. This depends on the definition of off-peak and on-peak, and on the specific control algorithm, which appear to refer to the load-generation balance of the local system. These definitions should be clarified. Similarly,

the term ‘exceeding power’ used on Page 52 is not commonly used and should be defined.

- Please consider defining each abbreviation at the first time of use. Some abbreviations are defined in text, e.g. CCL and DCL on Page 25, but the majority are not
- On Page 42, the description ‘The capacitance Ctot was split into two parts…and second without (C)’ is a little confusing. Please consider explicitly stating ‘the second (C) without series resistance’.
- Please discuss the EMC filter results with of Figure 21 with respect to the previously introduced harmonic limits.
- Please consider including a simplified flowchart of the LabVIEW figures included in Section 3.4.4.
- There appears to be a Ton^{2} term missing in the integration in (3-7) and (3-8)

Questions:

- Page 21. It was stated that the battery system was designed to supply the supply for 1hr. Why was this value selected?
- How was the data in Fig. 7 obtained?
- In Table 9, the switching frequency was stated as 800 Hz but the reasoning for this was not clear. Why was this value chosen?
- Some care is taken to design an EMC filter but there is no discussion of results pertaining to the performance of this aspect (e.g. compliance with IEC standards). In the conclusion it is stated this was not included in the final system but, imagining that the EMC filter was included, what, if any, modifications would be required to the implemented verification/measurement system to analyse the performance of the EMC filter, particularly with respect to compliance with harmonic standards and system efficiency?
- What power factor value was used for the PV inverter? Table 7 shows that this is a function of the output power.
- Following on from the question above. Throughout the thesis, calculations assume a unity power factor. However, as shown in Table 7, in real systems, the power factor may be less than unity. What, if any, impact would this have on the design and operation of the proposed system.
- The first logic test of Figure 33 is confusing as Ppv itself does not indicate the state of the balance of power between generation and load (i.e. excess or lack of power). Should this state test not also include local consumption?
- The values of the load and generation presented in the results section do not match those in the test description (Table 15 and Table 16). What is the reason for this?

----

reviewer of master’s thesis